Implementing Occupancy Sensor Lighting Controls in Cal Poly CIC Lab Classrooms

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Occupancy sensors are lighting control devices that automatically turn lights on when they detect motion, and off when motion is not detected for an allotted time period. These sensors can be applied virtually anywhere, indoor or outdoor, and can provide substantial energy savings. One application that does not utilize occupancy sensors often enough is classrooms. Cal Poly currently utilizes an outdated toggle switch system that students do not maintain properly, wasting a large quantity of energy. This paper will examine the maintaining of the current lighting control system in Cal Poly's Construction Innovation Center (CIC) lab classrooms; the operating cost of the current lighting system, the specifics of a proposed occupancy sensor system, the payback period of the occupancy sensor system, new industry knowledge, conclusions of the study, lessons learned, and recommendations for implementing occupancy sensors. The project determined an excellent occupancy sensor system to install in the CIC; however, the precise consumption of the current lighting system was not determined due to unavailable data. Educated assumptions based on personal experiences and observations were factored into calculations. As a result, the project encourages the implementation of an occupancy sensor system, specifically the wireless Lutron Energi TriPak. Altogether, this experience offered valuable lessons, which included methods to overcome obstacles, as well as the importance of valid communication, detailed planning, and punctuality.

Key Words: occupancy sensor, lighting, controls, Cal Poly, classrooms

Introduction

Occupancy sensors are a simple, affordable method to reduce lighting energy consumption. These sensors are mounted on ceilings or walls, and automatically turn the lights on in a space when motion is detected. When the sensors do not detect motion for a preset amount of time, then the lights turn off, creating an opportunity for energy savings. A large number of occupancy sensors exist, each with different features that vary the price, comfort levels, and overall sustainability of a lighting system. A collaborative paper led by Bill Von Neida reveals the results from a case study where classrooms with manual controls were monitored for their lighting energy consumption, which determined the amount of wasted energy when rooms were unoccupied. The study revealed that during 20% of daytime and 17% of nighttime, the lights were left on in an unoccupied room. According to the document, the installation of occupancy sensors would drastically reduce levels of energy waste. When compared to the baseline, daytime energy savings would reach over 80%, while achieving over 50% at night. Some sensors can even exceed these numbers when their settings are adjusted to maximize sustainability. As a result, occupancy sensors can save hundreds of dollars on annual electricity bills, while preserving fossil fuels and other energy sources.

The Cal Poly Construction Innovations Center (CIC) hosts a large portion of classes for Cal Poly construction management students. If they are enrolled in a lab course, they can access their lab classroom in the CIC at any time of the day. With constant access to the labs, it is probable that an even higher percentage of energy is wasted in the Cal Poly lab classrooms than those studied by Bill Von Neida. Personal experiences and observations have proven that these labs are often lit with no occupants inside, which wastes alarming amounts of energy, increases energy bills, and harms the environment as more carbon dioxide is released to produce more energy. Cal Poly must address their current energy-wasting practices by considering the installation of lighting occupancy sensors.

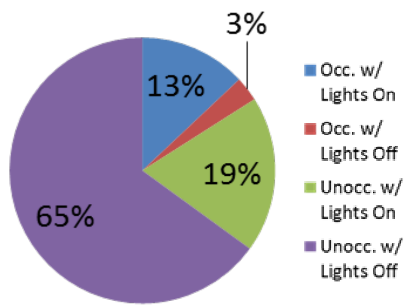

Figure 1: Classroom Lighting Conditions (Von Neida)

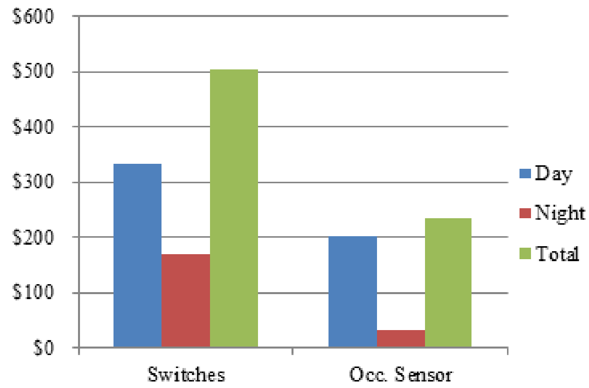

Figure 2: Classroom Lighting Conditions (Von Neida)

The Cal Poly Construction Management program exemplifies excellence in construction education, as represented in the Construction Innovations Center (CIC) each day. One focus of the program is sustainability, where students learn to build efficiently for a greener future. Since the CIC strived to achieve LEED-EB certification as an existing building in 2012, it has not taken advantage of one of the simplest techniques to reduce consumption and increase savings, which is an automated lighting control system. Currently, the lab classrooms of the CIC utilize manual toggle switches that are assigned to specific lights in each lab. Due to the developing technology in the lighting controls industry, the current system is not only outdated, but relies too heavily on human control. CIC lab classrooms during non-lecture hours usually have all light fixtures turned on at full capacity with very few, and sometimes zero, occupants inside. To combat this, Cal Poly must install a new automated lighting control system, such as occupancy sensors. The Lutron Energi TriPak occupancy sensor system provides easy setup, spectacular performance, and vast savings at a low upfront cost. With this Lutron system, Cal Poly will reap many benefits, reduce our carbon footprint, and exemplify how it is a forerunner in green construction education.

Methodology

The objectives of this research are as follows:

- To present the need for a new lighting control system in the CIC labs
- To identify the maintenance required for the current lighting control system
- To calculate the operation cost of the current lighting system
- To determine an excellent occupancy sensor system to implement in the CIC labs
- To discover the payback period of the proposed occupancy sensors

The methodology chosen for this study included fieldwork and qualitative research methods. A student survey, which represents fieldwork research, was sent out to all Construction Management students to determine how well they manage the current lighting control system. The survey focused on how often they adjust the lights, if they find empty classrooms fully-lit, and other questions to establish a basis of how much energy is being wasted with the current system. As for qualitative research, the researcher gathered cost data and calculated the operating cost for the current lights. This information was used to decide whether or not an occupancy sensor is needed in the CIC lab classrooms. Additional qualitative research occurred with identifying the ideal occupancy sensor system to install, along with its components, various features, upfront cost, and payback period.

Understanding the current lighting control system is essential in various ways. First of all, its proposed technical performance must be understood to determine whether it currently performs up to its standard. According to the CIC construction documents and lighting fixture schedule, one switch controls a single up-light for 2 rows of light fixtures, while another switch controls two down-lights for the same rows of fixtures (California Polytechnic State University). In other words, each switch turns on a portion of the lights. Therefore, when all switches are turned on, the room is lit at full capacity. Typically, the rooms are lit at full capacity during lecture hours. The next question regarding the existing lighting controls is whether or not students maintain the system to conserve energy. This system provides the ability to reduce wasted energy. It can be properly managed by turning lights off before leaving the classroom or only turning on the necessary lights for a workspace, as opposed to igniting all the lights. However, this current system can also waste a substantial amount of energy, an issue that inspired this study. Simply observing these lab classrooms, lights are often turned on at full capacity when there are few to no people occupying the room. To identify whether this observation is mere coincidence or factual, a student survey would come in handy.

Composing survey questions

Another significant means of methodology includes an online survey directed to Cal Poly's construction management majors and minors. These individuals typically utilize these classrooms on a daily basis due to the wide variety of construction-related classes that are offered. The opinions of the students are essential because they are responsible for managing the use of the current lighting system, and may not even be aware of their role of conserving energy. To address the need for an occupancy sensory system, this survey will determine whether the current system is being utilized conservatively or carelessly. The survey's introduction informs survey respondents of its focus on the CIC CM Building lab classrooms, as well as the significance of a proposed occupancy sensor system. Also included is a brief, technical summary of the current lighting control system to raise awareness of how the toggle switches can be operated for specific uses, to conserve energy. Some of the survey questions will be applicable to the current toggle-switch system, but mainly its effectiveness, as well as student use and awareness of the system. The remaining survey questions shall address the new occupancy sensor system and gain opinions on its implementation.

Survey Results

The survey yielded a total of 39 responses from anonymous construction management students, whether majors or minors. Based on the results, the overall consensus amongst respondents favored the installation of occupancy sensors in the CIC lab classrooms. Nonetheless, the responses indicate that a portion of the students adequately maintained the current system, conserving a moderate amount of energy. One factor to consider is that the ages of respondents varies, as some may be upperclassmen who are more familiar with the lighting system, and consequently, are more mindful to operate it efficiently. Another item of consideration is that there is not a direct correlation between the non-lecture hours of classroom use and the individuals who do not manage the system properly. If this survey was not anonymous, then each respondent's answers could be compared throughout the survey, which helps narrow down the time intervals of zero occupancy with full lighting capacity. Overall, the survey results reveal that the lighting system is not managed properly and wastes energy, so an occupancy sensor system should be implemented.

Of the 39 respondents, 15.4% have never turned on the lights in any of their lab classrooms, or at least do not remember this occurrence. Another 56.4% of respondents turn on the lights only once per every few weeks. This could be a coincidence if they simply entered the classroom shortly after another student entered it and turned the lights on, or exited but forgot to turn the lights off. Although this may be the case, it is assumed that these individuals consistently walk into a fully-lit classroom with only few to no occupants within. To make matters worse, these students may be on the same weekly schedule, allowing energy waste to remain consistent.

An unfortunate 28.2% of respondents have never turned the lights off. Of these 39 students, 20.5% have never thought about turning the lights off. Even so, there is the chance that a person, or group of people, still occupied the room as these individuals left. However, this does not provide an excuse for the 7.7% of individuals who claim to never turn the lights off, even if they are the last person to leave. Some other students turn off the lights sometimes, but not every time, even if they are the last one to leave. This would be only a minor issue if it were a few students, but data shows a colossal 35.9% of respondents fit into this category. The numbers certainly accumulate over time, and the sum of wasted energy continues to rise.

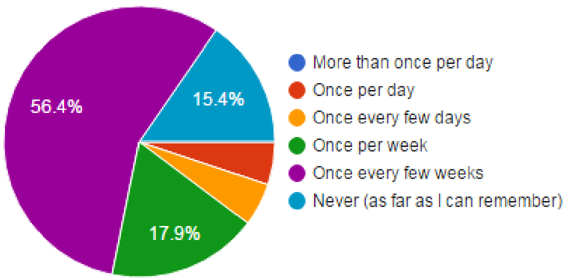

Figure 3: Frequency that Students Need to Turn Lights On (Packard)

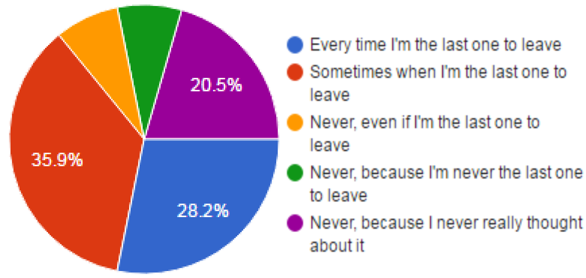

Figure 4: Frequency that Students Turn Lights Off (Packard)

Perhaps the most impactful survey question directly addresses the amount of wasted energy in these classrooms, based on lack of efficient management of the current system. The question regards the number of students who walk into empty classrooms to find the lights at full capacity. While 25.6% of respondents experience this occurrence only sometimes, a staggering 46.2% report that they walk into an unoccupied, fully-lit room often. Finally, 20.5% found that this situation occurs every single time they enter their lab classroom. Again, the amount of time these lights were left on is not identified, but even short periods of time waste a substantial amount of energy when considering how many students find this as a regular situation. The current lighting control system places the responsibility of turning lights off directly with the construction management students, who tend to forget to switch off the lights. As previously mentioned, a smaller percentage of respondents had never turned their lab classroom's lights off. This indicates that many of the students who failed to respond to the survey make up a large portion of those who often leave lights on in the labs, to which the survey respondents walked into.

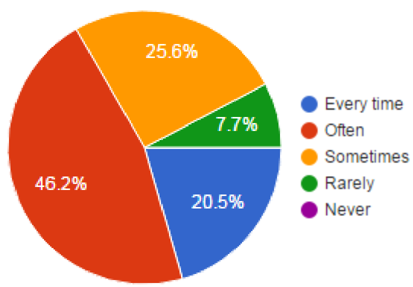

Figure 5: Frequency that Lights are On in Unoccupied Classrooms (Packard)

Current System Cost Analysis

To further understand the need to utilize green construction methods on campus, it is important to note the current electrical usage on campus. The Cal Poly Facilities department tracks consumption of campus resources, such as electricity, water, and gas. Electricity consumption is relevant, since lighting systems require this particular type of power to operate. The goal was for Cal Poly Facilities to identify the electricity used solely in the CIC, as opposed to campus-wide energy use. Unfortunately, previous AFD reports have only offered this campus-wide consumption levels, and this remains true to this day. Although the Secondary Unit Substation in the basement of the CIC has a Supervisory Control and Data Acquisition (SCADA) fiber optic connection to Facilities, data was not available for review. Expressing the vast financial impact and inefficiencies of the current lighting systems will further support the need to change to newer, more efficient lighting control system.

Most, if not the entire campus classrooms have implemented a similar toggle-switch system to those in the CIC labs. With this in mind, the campus consumption rates will correlate with the actual CIC electrical use, due to the similar lighting control systems. The only issue with this comparison is that all other classrooms will most likely differ in student-use during non-lecture hours. Furthermore, some facilities operate their lights at full capacity non-stop throughout each day. Even still, implementing occupancy sensors to reduce energy consumption in the CIC directly impacts campus-wide consumption.

According to Eric Veium, an Energy and Sustainability Analyst for the Facility Services branch of the Cal Poly Administration and Finance Department (AFD), “Cal Poly’s annual blended energy rate is $0.11/kWh” (Veium). Simply put, it costs Cal Poly $0.11 for each kilowatt used in one hour. Although this does not represent the specific lighting consumption cost of the Construction Innovations Center, it is assumed that this rate can be applied for the building. This $0.11/kWh is a key component in calculating the cost analysis of the current system.

Cost Analysis

Since Cal Poly AFD does not currently log the number of hours that the CIC lights are turned on, an assumption must be made as to how many hours per day that the lights are lit in each lab classroom. The current class schedule reveals that some labs are used at least 3 to 4 hours per day for mandatory lecture hours. Other lab classrooms host even 2 classes per day, which means the lights will definitely be turned on for at least 6 to 8 hours per day, depending on the class subjects and allotted units. Lights need to be turned on during these lecture times, so there is no opportunity to save energy here. However, based on personal experiences and observations, it was assumed that these classrooms’ lights are turned on an additional 12 hours per day, during non-lecture hours. In this 12-hour span, students utilize their labs to study, work on schoolwork, and even just relax. Nonetheless, the survey results prove that students do not always occupy these rooms during non-lecture hours, but certainly leave the lights on often. Considering lecture and non-lecture hours, the CIC lab classroom lights are lit for approximately 16 to 18 total hours per day. Survey results support these numbers, as students indicated that they use their respective lab classrooms throughout all timeslots of a 24-hour period. In addition, 64.1% of students fail to turn off the lights regularly, wasting vast amounts of energy and raising electrical costs. Whether the classrooms are occupied or unoccupied, the lights are turned on for about 12 extra hours each day, outside of lecture hours.

Now that the hours of use have been determined, the next component to factor into the equation is the amount of watts that are consumed per hour and the cost of that power. According to sheet E4-03 of the CIC project plans, each 4-foot light fixture consumes 96 watts using a High Power Factor Electronic Ballast, as shown below:

G		4" SUSPENDED INDIRECT FIXTURE COMPLETE WITH ONE PIECE EXTRUDED ALUMINUM HOUSING, SPECULAR ALUMINUM REFLECTOR, HPF ELECTRONIC BALLAST, ICLS COMPATIBILITY AND MOUNTING ACCESSORIES AS REQUIRED. LAMP OPERATION: 2-LAMP GENERAL LIGHTING MODE AND 1-LAMP A/V LIGHTING MODE.	3	32	F32/T8	ELECTRONIC	1	277	FINELITE ALERA CORELITE	FORM 10 "IDC" SERIES "A1" SERIES	PENDANT

Figure 6: Light Fixtures in CIC Lab Classrooms (California Polytechnic State University)

There is a quantity of 30 of the 4-foot light fixtures in each room, and this quantity is multiplied by 96 watts per fixture to produce 2,880 total watts consumed per hour. Since Cal Poly AFD provided a value of $0.11 per kilowatt-hour, the 2,880 total watts must be converted to kilowatts by dividing 1,000. Finally, this dividend value is multiplied by $0.11 per kilowatt-hour, equaling an operating cost of approximately $0.32 per hour for a single classroom’s lights when they are turned on. When considering the 12 non-lecture hours of lighting consumption per day, this $0.32 per hour amounts to $1,170.89 per classroom in one school year of about 308 school days, or 3,696 hours. Assuming all lab classrooms consume the same amount, this value increases to $14,050.71 for all nine lab classrooms. Calculations on the current operating cost are found in Appendix A.

Proposed Occupancy Sensor System

With all data gathered and analyzed, the final step is to select an occupancy sensor system that provides the best performance, lowest upfront cost, and most reliability. Professional assistance is important to gather the most-qualified opinions. With decades of experience in the lighting industry, Darrell Packard, the current CFO and Principal of Associated Lighting Representatives, has witnessed extraordinary development of various lighting controls, especially occupancy sensors. Darrell’s recommendation on occupancy sensors will be taken very seriously, as he can directly contact manufacturers for product specifications, net costs, and functions.

Considering the cost of the chosen system, the payback period can be calculated. Based on its rates of energy savings, the new occupancy sensor system will ‘pay for itself’ with all the money Cal Poly saves on electricity. To reiterate, reduced energy consumption also leads to reduced levels of carbon dioxide that are released into the environment from burning fossil fuels. Lowering the consumption of light fixtures can provide significant energy savings, considering that “lighting accounts for an average of 38 percent of electricity used in commercial buildings—more than any other building system” (Lutron). With its monetary savings and green characteristics, it seems as if there are no negatives to a new occupancy sensor system. However, the system must adhere to the needs of these specific CIC classrooms and the students’ learning environment. Research shows that if an appropriate occupancy sensor system is not implemented in a space, or if the chosen sensors are not adjusted properly, they may shut off the lights while people are still occupying the space. To prevent this, Cal Poly must implement sensors strong enough to detect the slightest motion, while having a great range of motion detection. Darrell Packard will identify the most effective system to his greatest ability.

After analyzing the project details, it turns out that the Construction Innovations Center project plans specified potential occupancy sensors to install in the lab classrooms. Clearly, these proposed sensors were not actually installed, most likely due to value engineering by the contractor during construction. Nonetheless, these lab classrooms were designed to incorporate an occupancy sensor system. In order for Cal Poly to maximize their energy savings, the classrooms should implement Lutron Energi TriPak occupancy sensors and accompanying devices. This Lutron system features the Radio Powr Savr occupancy sensors with PIR, or passive infrared, technology that detects even the slightest motion in a 1,500 square-foot area. Accompanying the sensors is the PowPak relay module with Softswitch capabilities, which relays the signal from the sensors to the lights, allowing them to turn on automatically. The Softswitch technology strengthens the performance of the PowPak over the long lifespan of the system. Also included in the system are Pico wireless controls that turn the system on and off. These Pico remotes are mounted on the wall in place of the existing light switches of the CIC classrooms’ current systems. All components of the Energi TriPak system work seamlessly to conserve “30 percent – and up to 60 percent – on lighting costs” (Lutron). According to the project specifications for the 100% construction documents of the CIC, the Lutron system will certainly comply with its requirements.

Construction Innovation Center construction specification section 16145-5, titled Lighting Control Devices, suggests various types of occupancy sensor technologies. For sensors to be installed in the CIC lab classrooms, they must represent either passive infrared, ultrasonic, or dual-technology. As previously mentioned, the Lutron Energi TriPak system features passive infrared technologies, thus satisfying this requirement of the CIC labs. Furthermore, the detailed requirements for a CIC passive infrared system state that it must cover an area of “1000 sq. ft. when mounted on a 96-inch-high ceiling” and “detect occurrences of 6-inch-minimum movement” (California Polytechnic State University). Although the lab classroom ceilings are higher than this 8-foot requirement, the Lutron sensors can be wall-mounted at any height, and will satisfy this 8-foot height requirement. Also, the state-of-the-art technology programmed into these sensors has no problem detecting even the slightest motion.

Due to its wireless nature, the Lutron Energi TriPak stimulates other, more subtle benefits. Typical hard-wire systems require a number of other materials, primarily wires. The Lutron Energi TriPak system eliminates the cost of excess wires, conduit, and other electrical materials. If fewer materials are needed, then there is a faster installation time, reducing the labor cost as well. With an easy setup, the systems should require no more than one hour per classroom. As the hired electrician or handyman advances from classroom to classroom, they become more familiar with the system and can install it faster. It may take the electrician an hour to install the first system, but this time will decrease with more installation experience. Realistically, all nine classrooms should have the Lutron occupancy sensors implemented in one day’s work. Once installed, the sensors can even be moved as needed throughout the room, another benefit of the wireless system.

Operation

In order for the lights to even turn on, they must be manually switched on each day by pressing buttons on the Pico remotes. Now that the system is operating, the sensors will begin detecting motion throughout the classroom. If all occupants have left the room, and the programmed shut-off time has been exceeded, then the sensors will turn off the lights. However, the occupancy sensor system continues to operate, even with the lights off. Subsequently, when individuals walk through the door again, the lights will switch on. The system will remain in this state of operation until somebody presses the ‘off’ buttons on the Pico remotes. When this is done, the lights will no longer turn on when there is motion inside the lab classroom. For the system to turn back on, somebody must manually switch them back on by pressing the Pico remote ‘on’ button.

Occupancy Sensor Payback Period

The specific number of kilowatt-hours that these classrooms consume is could not be determined by Cal Poly AFD. To do so, electricians would need to install devices called lighting loggers to tap into the current system and log the quantity of kilowatt-hours that the lights use. Therefore, the assumed 12 non-lecture hours per day that the lights are turned on can assist in calculating the Lutron Energi TriPak system's payback period. A payback period is the amount of time that it takes for the new occupancy sensor system's generated savings to pay for the total upfront cost of the system, including materials and labor. However, this payback period is unique in that a desired payback period must be chosen before-hand, such as one year. The final value that must be determined is the ratio of the total number of hours that must be conserved in an entire school year. To begin calculating the one-year payback period, the total cost of $532 per classroom is divided by the operating cost $0.32/hour per classroom. This equals roughly 1,680 hours, meaning the new system needs to conserve 1,680 hours of consumption to pay for itself.

One factor to address is that there are approximately 44 school weeks, or 308 days, per one calendar year when factoring out vacations and school breaks. Then, these 308 days are multiplied by the 12 non-lecture hours per day of light consumption, totaling 3,696 hours. Finally, to find the ratio of conservation hours to consumed hours, 1,680 hours is divided by 3,696 hours, and equals 0.454. As a result, the lights must be turned off 45.4% of the 12 non-lecture hours, or 5.4 hours, to achieve a one-year payback. When referring to the survey results in how often the rooms are unoccupied with the lights on, this 5.5 hours per day seems plausible. However, calculating the same math but for a two-year back requires only 2.75 hours of the lights turned off, a very realistic goal. Payback calculations can be found in Appendix A.

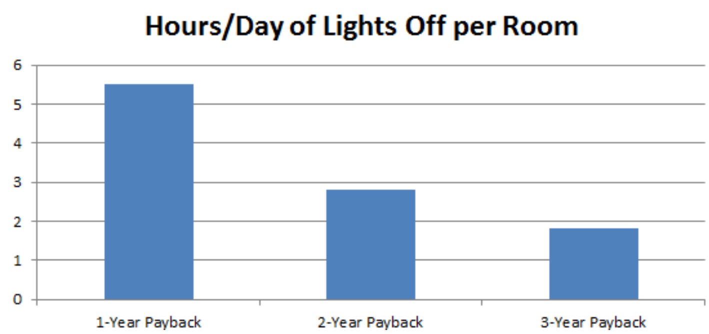

Figure 7: Hours per Day of Lights Off
Needed for Payback

New Industry Knowledge

The new knowledge conveyed through this project includes the benefits of replacing an outdated lighting control system in an existing university classroom with a new occupancy sensor system. Various databases provided very limited information regarding occupancy sensors implemented in university classrooms. These sensors have been applied to existing buildings before, such as offices, warehouses, and even homes. However, there is little evidence showing that college campuses have installed any new lighting control systems to reduce energy consumption.

As the construction industry advances into the future, newer, more sustainable practices are appearing. A building that houses one of the nation's top Construction Management programs should exemplify these sustainable tactics. As the industry develops, so should the Construction Innovations Center at Cal Poly. Installing an occupancy sensor system is an achievable goal, both financially and timely, to keep up with the times. Occupancy sensor controls are a method of green specialty construction for Cal Poly's Construction Management students to experience first-hand.

Conclusions and Future Research

The Cal Poly Construction Innovations Center currently utilizes a manual switch lighting control system. Various studies, as well as a survey sent out to all Cal Poly construction management students, reveal that these manual switch systems tend to waste energy, specifically when the rooms are unoccupied but lights are left on. The survey sent out to construction management students determined that over 64% of students do not always turn of the lights when they should, and over 92% sometimes, often, or always find unoccupied classrooms lit. Observations have determined that there are about 12 hours outside of lectures that the lights are turned on, which wastes a lot of energy when considering how often students aren't occupying their rooms. This wasted energy could cost Cal Poly over $14,000 in one school year for the entire CIC. This evidence encourages the need to implement a new lighting occupancy lighting control system, which have been proven to reduce energy consumption by substantial proportions. The Lutron Energi TriPak system appropriately addresses the size and motion-detection specifications required in the CIC lab classrooms, while remaining very affordable. On top of its unparalleled performance, the Lutron occupancy sensors conserve enough energy to reasonably payback their initial cost within one year. Cal Poly needs to address their waste of energy in the CIC lab classrooms, and the Lutron Energi TriPak is the solution.

Lessons Learned

The process of completing this senior project encouraged the improvement of various communication skills. Three means of communication used throughout the duration of this project include emails, phone calls, and face-to-face meetings. Emails suffice at inopportune hours of the day, or when deliverables and questions regarding the project are not urgent. Phone calls can address these items at a faster rate through direct conversation, but still lacks a personal touch that envelops full understanding. Finally, personal meetings are more beneficial than emails and phone calls because they allow fast, in-depth understanding of topics discussed, and have a more personal touch that strengthens the relationship between the two parties. Meetings were the preferred means of communication with Lonny Simonian throughout the duration of this project, although email conversations were conducted most frequently. As distance was a factor, only phone calls were utilized in communicating with Darrell Packard to receive guidance reviewing the CIC electrical plans and analyzing potential occupancy sensors.

Time management skills also developed as the project progressed. As submittal deadlines approached, setting incremental deadlines for the completion of smaller tasks proved very effective. This method of time and project management allowed the project to constantly advance toward its completion. Furthermore, it addressed any issues at an early stage, which could be discussed with Lonny Simonian and handled either with in-person meetings, or simply emailing him. Proper time management led to both decreased work load and stress levels as the final project deadline approached.

Lastly, the project enhanced problem-solving techniques. Throughout various stages of the project, a few issues arose which pertained to different topics. One particular issue occurred when the Cal Poly Facilities Department could not provide significant data about the CIC lighting system's current energy consumption. As a result, alternate information needed to be obtained to strengthen the same argument; the argument that the current system consumes more energy than necessary. To reiterate, reducing energy consumption saves the university money on the electricity bill, while reducing the human carbon footprint as fewer fossil fuels are burned to produce more energy. Lonny Simonian suggested an alternate route of utilizing calculations to discover the financial impact of the current lighting system in the CIC as a whole building. Another problem encountered during this project was the lengthy time-span of observing E-plans and interviewing with Darrell Packard to determine the ideal occupancy sensors to implement. Two individuals may have different schedules, so taking advantage of aligned free time is vital. Fortunately, this task did not require much time and further analysis, so it did not hinder the project's completion.

Future Research

For future research, I would recommend gathering hard, accurate data of lighting consumption in classrooms. This would prevent the need to make assumptions, and would allow researchers to determine the actual cost of the current system, as well as the precise payback period of a proposed new system to implement. The consumption data can be obtained with the use of lighting loggers, which analyze the flow of consumption that lights use. Cal Poly's light fixtures are hardwired, and would require an electrician to install lighting loggers to tap into the current system. Although this would present accurate data, it would create labor and materials costs, as well as time consumption to collect the data. Nonetheless, these steps are necessary in determining the most accurate data possible. Occupancy sensors are progressing in various applications, and their implementation in classrooms has steadily increased over time. With more efficient performance of occupancy sensors and the recent development of strict energy codes, they are becoming more appropriate to include in either new or existing classrooms. Future researchers should make sure these new sensors comply with California energy codes such as Title 24, and could choose exact locations to install the sensors in various classroom layouts to achieve maximum energy savings. Moving forward, researchers could use the data from this project to create a program to actually get the occupancy sensors installed in the Cal Poly CIC lab classrooms, and perhaps other areas of campus.

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Appendix A

Calculations

Cost Per Room

96 (Watts/hr per 4’ fixture) **X** **30** (4’ fixtures per room) **=** **2,880** (Watts/hr per room)

$$\frac{\textbf{2,880}\text{ (Watts/hr per room)}}{\textbf{1000}\text{ (Watts/Kilowatt)}} = \textbf{2.880}\text{ (kW/hr per room)}$$

2.880 (kW/hr per room) **X** **$0.11** (per kW-hr) **=** **$0.3168** (per hour, per room)

Conservation Hours Needed to Achieve Payback Periods

$$\frac{\textbf{\$532.00}\text{ (per Energy TriPak system)}}{\textbf{\$0.3168}\text{ (per hour, per room)}} = \textbf{1.679.29}\text{ (conservation hours needed to payback system)}$$

44 (weeks per school year) **X** **7** (days per week) **=** **308** (days per school year) **X** **12** (non-lecture hours lights are on daily) **=** **3,696** (non-lecture hours consumed)

$$\frac{\textbf{1,679.29}\text{ hours of conservation}}{\textbf{3,696}\text{ non-lecture hours lights are lit in one school year}} = \textbf{0.454} \;\textbf{X}\; \textbf{12}\text{ (non-lecture hours consumed)} = \textbf{5.5}\text{ (conservation hours for 1-year payback)}$$